6 Methods of stress analysis

6.1 Analytical methods for mine design

Basic issues to be considered in the development of a mine layout include the location and design of the access and service openings, and the definition of stoping procedures for ore extraction. These issues are not mutually independent. However, geomechanics questions concerning stoping activity may be more pervasive than those related to the siting and design of permanent openings, since the former persist throughout the life of the mine, and possibly after the completion of mining.

The scope of the problems which arise in designing and planning the extraction of an orebody can be appreciated by considering the implementation of a method such as room-and-pillar mining. It is necessary to establish parameters such as stope dimensions, pillar dimensions, pillar layout, stope mining sequence, pillar extraction sequence, type and timing of placement of backfill, and the overall direction of mining advance. These geomechanics aspects of design and planning must also be integrated with other organisational functions in the planning process. It is not certain that this integration is always achieved, or that economic and geomechanics aspects of mine planning and design are always compatible. However, it is clear that sound mining rock mechanics practice requires effective techniques for predicting rock mass response to mining activity. A particular need is for methods which allow parameter studies to be undertaken quickly and efficiently, so that a number of operationally feasible mining options can be evaluated for their geomechanical soundness. Alternatively, parameter studies may be used to identify and explore geomechanically appropriate mining strategies and layouts, which can then be used to develop detailed ore production schemes.

The earliest attempts to develop a predictive capacity for application in mine design involved studies of physical models of mine structures. Their general objective was to identify conditions which might cause extensive failure in the prototype. The difficulty in this procedure is maintaining similitude in the material properties and the loads applied to model and prototype. These problems can be overcome by loading a model in a centrifuge. However, such facilities are expensive to construct and operate, and their use is more suited to basic research than to routine design applications. An additional and major disadvantage of any physical modelling concerns the expense and time to design, construct and test models which represent the prototype in sufficient detail to resolve specific mine design questions. The general conclusion is that physical models are inherently limited in their potential application as a predictive tool in mine design. Base friction modelling provides an exception to this statement. If it is possible to deal with a two-dimensional model of a mine structure, and to examine discrete sections of the complete mine layout, the procedure described by Bray and Goodman (1981) provides a useful and inexpensive method for
design evaluation. The method is particularly appropriate where structural features exercise a dominant role in rock mass response.

A conventional physical model of a structure yields little or no information on stresses and displacements in the interior of the medium. The earliest method for quantitative experimental determination of the internal state of stress in a body subject to applied load was the photoelastic method. The principle exploited in the method is that, in two dimensions, and for isotropic elasticity, the stress distribution is independent of the elastic properties of the material, and is the same for plane stress and plane strain. In its original application, a two-dimensional model of a structure was prepared from a transparent material such as glass or plastic, and mounted in a beam of monochromatic, polarised light. Application of loads to the model, and passage of the light beam through an analyser onto a screen, produced a series of bands, or fringes, of light extinction and enhancement. Generation of the fringes is due to dependence of the propagation velocity of light through the medium on the local principal stress components. A fringe, also called an isochromatic, represents a contour line of constant principal stress difference. Thus a fringe pattern produced by a photoelastic model represents a mapping of contours of maximum shear stress throughout the medium. Calibration of the system allows the shear stress magnitude of any contour level to be determined. For excavation design in rock, it is necessary to establish the distribution of principal stresses throughout the medium. Thus in addition to the maximum shear stress distribution, it is necessary to establish contour plots of the first stress invariant. Since, as is shown later, this quantity satisfies the Laplace equation, various analogues can be used to define its spatial variation in terms of a set of isopachs, or contour plots of $(\sigma_1 + \sigma_3)$. Taken together with the photoelastic data, these plots allow the development of contour plots of the principal stresses throughout the problem domain.

It is clear from this brief discussion that the photoelastic method of stress analysis is a rather tedious way of predicting the stress distribution in a mine structure. It is therefore rarely used in design practice. However, the method is a useful research technique, for examining such problems as blocky media (Gaziev and Erlikmann, 1971) and three-dimensional structures (Timoshenko and Goodier, 1970) using the frozen-stress method.

A major detraction from the use of physical models of any sort for prediction of the rock mass response to mining is their high cost in time and effort. Since many mine design exercises involve parameter studies to identify an optimum mining strategy, construction and testing of models is inherently unsuited to the demands of the design process. Their use can be justified only for a single, confirmatory study of a proposed extraction strategy, to verify key aspects of the mine structural design.

6.2 Principles of classical stress analysis

A comprehensive description of the fundamentals of stress analysis is beyond the scope of this book. Texts such as those by Timoshenko and Goodier (1970) and Prager (1959) may be consulted as general discourses on engineering elasticity and plasticity, and related methods of the analysis of stress. The intention here